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HOW FUNDING AND POLICY AFFECT ACCESS TO AND MODERNIZATION OF MAJOR AIR FORCE GROUND TEST INFRASTRUCTURE ASSETS

by

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A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

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6 April 2017

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Biography

Thomas Fetterhoff is assigned to the Air War College (AWC), Air University, Maxwell AFB, AL. Prior to attending AWC, Mr. Fetterhoff was the Technical Director of the Arnold Engineering Development Complex (AEDC). He served as the AEDC Technical Authority for all AEDC flight test, ground test, and technical support programs. He advised the Commander on all critical technical issues. Fetterhoff ensured seamless integration of more than $400M in technical products across AEDC units located at Arnold AFB, Wright Patterson AFB, Holloman AFB, and Eglin AFB. Before becoming the AEDC Technical Director he was the Technical Director and Senior Civilian of the Arnold Engineering Development Center Test Division. He was the Technical Lead for a government and contractor work force of 800 personnel executing $110M in development tests annually for the DoD, other government agencies, allies, and commercial customers at the world's largest ground test flight simulation facility. The Test Division is responsible for programming, management, execution, and reporting for all test and analysis and evaluation programs in all of the center's wind tunnels, gas turbine sea level and altitude test cells, space chambers, altitude rocket cells, ballistic ranges, arc heaters and other aerospace test units including Hypervelocity Tunnel 9 in Maryland and the National Full Scale Aerodynamics Complex in California. Before becoming the test division technical director he was the chief of the 649th Test Systems Squadron at Arnold Engineering Development Center, government civilian, military and contractor organization with 130 personnel and a budget of $30M. He also served as the Executing Agent for the Office of the Secretary of Defense's Test and Evaluation Science and Technology Advanced Propulsion Test Technology (APTT) Area managing a broad spectrum of Test Technology Development Projects with a value of more than $90M.

Abstract

Funding and use policies, modernization processes, and a lack of coordination between technology developers, system developers, program offices, and test organizations all negatively impact the ability of the national developmental test infrastructure's ability to support early engineering and development of weapon systems. Accurate, timely world-class test capabilities are critical, because the results affect the ability of programs to be completed successfully.

For programs to benefit, testing must be accomplished in a timely manner and the test capability must be capable of meeting the technical needs of the development program. The adequacy of this capability and throughput capacity depend heavily upon funding and use policies. Funding and use policies hamper effective collaboration between developers and testers and restrict the coordination of future test requirements. These policies can be modified to improve test facility capability and capacity. It is important to implement these changes so that the Air Force department can save time and money while improving the performance of national technology and weapon systems programs.

Introduction

A nation's ability to field modern weapon systems depends directly on the quality of that nation's research, development, test and evaluation (RDT&E) capabilities. The facilities providing these capabilities play a key role in the development of aerospace systems.[i] The most critical weapon system and technology development programs must have access to the highest quality development test capabilities. The Air Force has spared no expense developing the very best national scale ground test capabilities in the world. However, these test capabilities are often underutilized or unavailable for support of important national programs. Funding and use policies limit the utilization of these test capabilities. For facility operators to effectively provide the needed capacity and capability, they must know and understand the future workload from both technical and throughput aspects. Once the workload is understood, funding and use processes must support the test capability owner's need to provide the required services. This paper assesses the funding and use processes that affect the ability of facility owners to provide effective test capabilities in a timely manner. Recommendations to improve these processes are provided.

Early development ground test facilities are critical to support both acquisition programs and technology maturation programs. Developmental testing facilities are utilized in systems development well ahead of a "Milestone A" program decision and are important to supporting programs throughout the program life cycle. These facilities are a critical source of engineering information for designers, maintainers, operators, and decision makers. The developmental test suite of capabilities is typically comprised of modeling and simulation; measurement, integration, hardware-in-the-loop, and installed systems test facilities; and open-air ranges. Both the Department of Defense (DoD) and the United States Congress have demonstrated continuous

interest in the adequacy of Test and Evaluation in the acquisition process. These organizations have commissioned a number of studies in an attempt to improve the development processes. Many of the recommendations of these studies have been codified in law or DoD directives. One recurring theme in these studies is a clear correlation between system failure and inadequate testing or an inadequate response to test results.[iiiii]

Inadequate early developmental testing can be the result of a cost tradeoff between high and low fidelity testing and often results in driving risk toward the end of the program where the cost to fix deficiencies is high. Inadequate testing is usually not the fault of the program office. On many occasions the issue is test facility availability or adequacy. Test facility adequacy and capacity issues are typically a result of funding shortfalls, rigid or inadequate funding processes, inadequate coordination with technology demonstrations, or the result of ineffective workload forecasting.

Changes in the funding process have made it more difficult to maintain facility readiness and a stable expert workforce. The decision to make funding available for facility modernization, new capability, or new capacity is usually after a major program "Milestone B" decision, well after the facility operators need to modernize or increase capacity to support technology demonstrations, assessments, or early weapons system development. The result is that emerging technology projects and innovative weapons programs must rely on the development capability available to programs at that time.

The collaboration between technology developers, system developers, and testers is critical to ensuring that test facilities have the capability and capacity to support all phases of the acquisition system life cycle. When technologists, testers, and systems developers collaborate, the technology risk to programs is reduced. Facility owners need time to develop new test

capability and capacity to support programs effectively. Changes in funding and use policy, along with improved workload and technology collaboration, would change the dynamic and reduce overall program risk and cost.

The Importance of Early Developmental Testing.

Early in the development of systems, testing is accomplished to obtain design information, find defects, and reduce risk throughout the development process.[iv] In light of the critical technology demonstrations and design information needed by program offices, the Test Community should be seen by program managers as a valuable part of the program office team. However, that is often not the case. A Defense Science Board (DSB) task force on Test and Evaluation Capabilities stated that "A consistent theme the Task Force encountered during the study is that testing is just another hurdle to be overcome in driving a program past its next milestone. The acquisition community views long periods of testing as evidence of system ineffectiveness while testing itself is viewed as an impediment to the systems success."[v] New fledgling programs often have close ties to the technology programs that have produced the enabling technologies needed by that program. The use of such high fidelity national test facilities drives the risk of technology readiness down for acquisition programs.

Cost and Quality of Testing.

One of the most used excuses to abbreviate a test program is the high cost of testing. However, the effectiveness of this decision is not supported according to a number of defense studies.[vi][vii] One DSB Study finding was that the cost of designing out system or technology shortfalls is far less than the cost of fixing them later:

> "The cost of testing is historically about 3 to 4% of the total program cost. That is relatively insignificant. With vital issues at stake, the minimal cost and very great

> value (return on investment) suggests we should maximize testing to discover any weakness or flaws as early as possible. Combat is the ultimate test, finding a fault in combat is the *ultimate cost of not testing.*"[viii]

The development program manager sees test as a large part of his development budget. But because the sustainment cost of the program is so high, the test cost of the program usually falls below five percent of the total program cost. Sustainment costs are heavily dependent on test adequacy in the development phase. A more holistic view of test cost is needed. While the development phase program manager does not directly manage the costs in the sustainment phase, he is responsible for overall estimated program cost. The total program cost must be considered by the system program office throughout the program life cycle.

Most developmental ground testing is done in either the system developer's test facilities or in national scale test facilities. In the aerospace sector, most national scale development test capabilities reside within the Air Force, at Arnold Engineering Development Complex (AEDC), and in the National Aeronautics and Space Administration (NASA) centers. Systems developers often use lower cost, inferior fidelity testing in lieu of national capabilities to reduce cost and maximize the use of organic capabilities. The unintended result of the utilization of inferior test facilities is that some design flaws are not found. Program offices then underestimate the risk of the design.

In the late 1990s all of the services reduced funding for organic test capabilities. The Air Force went a step further and moved the responsibility for developmental testing to the system developer.[ix] These decisions reduced test facility owner insight into programs and made the process of collaborating with system developers more difficult.

The services are often their own worst enemy when it comes to program oversight. Because of the large size, limited number of programs, and the difficulty getting new programs approved, the services are reluctant to delay or cancel programs. Performance problems in system development are often the result of broad waivers to testing granted to programs by the parent services and the dismissal of test results by the programs themselves.[x] A 2008 DSB Task Force Report on Developmental Test and Evaluation highlighted the issue of programs having increasingly high Initial Operational Test and Evaluation (IOT&E) suitability failure rates.[xi] "Early in the DSB study it became obvious that high suitability failure rates were a result of systematic changes that had been made to the acquisition process; and that changes in developmental test and evaluation could not remedy poor program formulation."[xii] At the very beginning of a program's life cycle the program is primarily constrained by cost and contracting issues. By passing along the cost of testing to programs, funding policy incentivizes program managers to minimize testing in early development. Early development is precisely when acquisition programs need the most information out of early development test facilities.

The cost of developmental ground testing is broken down into both direct costs, the costs attributed to executing the test project, and the indirect costs, the costs associated with facility and base ownership. The direct cost of development ground testing can be broken down to two basic costs. These costs are manpower and consumables. The consumables are dominated by fuel and power costs. Since manpower must be managed over the long term, funding of manpower as an indirect cost would alleviate problems with maintaining expertise. The indirect costs provide for security, base infrastructure, facility upgrades, routine and scheduled maintenance, and other overhead costs.

Decisions about who will utilize a facility or how the cost of that use is funded should be made at the level that best supports Air Force interests. "Improving the value of testing, not reducing the cost of testing, should be the goal in all future decisions regarding consolidation of activities, investment planning, and test resource management throughout the Department of Defense."[xiii] Program risk is ultimately taken by the service even when fixed price contracts are used for the acquisition. Since the department assumes the risk, decisions about an individual program's test cost may not be in best interest of the department. Facility readiness, capacity, or another program's needs might outweigh an individual program's interests. Funding and use policy could alleviate this issue by moving the decision process from individual programs to stakeholders in the community at large.

Funding and Use of National Test Capabilities.

After the inception of the AEDC in 1951, testing was conducted as a cost-free service to programs. Institutional funding for testing was provided by the service. This funding was utilized to perform test and evaluation, maintenance of test capabilities, test technology development, new capability planning, base support and overhead functions. Programs competed for access to these "best in the world" capabilities based on program priority. During these years, one would think that, lower priority programs and technology development programs would not be unable to get access to best in class test capabilities. However, due to weapon development program scheduling constraints, more than 30% of AEDC's capacity went to supporting system technology development efforts.[xiv] In the early 1970s the institutional funding accounts were abolished in favor of program funded testing. Facility workload collapsed as program offices and system developers eliminated tests from their programs, found lower-cost, inferior capabilities to utilize, or constructed their own capabilities at the prime

contractor's location. After the near closure of AEDC, Air Force funding became a mix of institutional and program funding. Today the direct cost of testing, operations, and non-routine maintenance is borne by the programs utilizing the capability. Overhead functions such as sustainment, base support, and modernization are funded by institutional accounts. Today almost none of the test capacity in Air Force development test capabilities is currently being utilized by technology developers. The result is that technology programs must utilize lower-cost, inferior test capabilities while capacity at the best facilities goes unused.

In 2002 NASA implemented this same funding model. The outcome was predictable. A number of facilities closed and workload dried up. The DoD commissioned studies by RAND[xv] and the Institute for Defense Analysis (IDA)[xvi] to understand the impact of the closures and the funding policy changes on DoD programs. The resulting interest by the Office of the Secretary of Defense (OSD) and Congress resulted in an increase in the NASA Aeronautics budget, which slowed the closure of NASA facilities. Recently NASA has returned to a policy of not charging for the use of test facilities when they deem it is in their interests. The DoD will benefit where interests overlap. The downside to this change is that DoD program will move to NASA facilities when they can get free testing reducing the collaboration between DoD testers and the DoD technology and system development organizations. This reduced collaboration between DoD testers and DoD technology developers hinders development of organic engineering talent within the DoD. This talent is needed to support the system development phase of the program.

Technology Collaboration

One way for development testers to forecast new needs and prepare for the weaponization of new technologies is to collaborate on the maturing of these weapons

technologies. This approach is hampered by the developmental test charge policies and the lack of funding available to use for such collaborations.

The gulf in technology transfer between the laboratory and acquisition, sometimes called the "valley of death" by technologists, has grown. In addition to funding constraints, collaboration between DoD technology developers and testers is hampered by organizational constraints and a lack of a collaboration policy. Technologists, who had access to the very best test capabilities before 1970, no longer have a low-cost, high-fidelity way to demonstrate capabilities. Technologists and acquisition programs no longer have a collaborator relationship; instead, the relationship became transactional.

Testers, technologists, and program managers can all benefit from a relationship based on collaboration. Technologists benefit by developing and demonstrating their technology in the facilities with the best flight simulation fidelity and the lowest measurement uncertainties available. They gain insight by having professional experimentalists develop test plans that will provide the very best insight into the technology's maturity. These benefits have narrowed the "valley of death" for technology development.

Testers gain a great deal of insight through collaboration with technologists. They can explore new test techniques and capabilities to improve simulation quality and reduce measurement uncertainty. It allows them to better understand what will be needed to transition this new technology to weapons programs. Testers develop insight into where technology is headed and where investment is needed to improve test capability, capacity, and technology to support the future Air Force.

Program managers benefit from insight into the weapon system gained by in-depth familiarity with the technologies that the program managers seek to transition. They gain

improved test quality and efficiency from new test techniques and test capability improvements developed during the technology development phase.

The Air Force gains a workforce, infrastructure, and process that has the opportunity to provide the best possible weapons at the lowest possible cost and shortest possible schedule. All three communities gain a developed workforce that has better insight and understanding of the entire acquisition process and the technologies that are being matured.

When testers, technologists and program managers compete for funds and each organization is trying to protect their funding lines at all cost, little collaboration results. For this important collaboration to succeed, each community must be funded to collaborate. Developmental testers, technologists and acquisition program managers must become allies not competitors. The resulting advanced concept demonstration programs could result in more technologies successfully transitioned with shorter acquisition schedules.

Capacity and Facility Planning

Public Law 81-415: Unitary Wind Tunnel Plan Act of 1949 and the Air Engineering Center Act of 1949 established AEDC and several major NASA test capabilities. Congress showed support for General Henry Arnold's vision that the United States never be caught behind in aerospace technology.[xvii] Congress directed that the administrator of NASA, then called National Advisory Committee for Aeronautics (NACA), and the Secretary of Defense develop a unitary plan, a coordinated plan to develop wind tunnels in DoD and NACA, and provide updates on that plan to Congress in accordance with scientific advances. These updates have never been provided and thus this method to secure funding for new capability has never been utilized by the Air Force.

Test facility owners are challenged to provide adequate capacity and capability to support early development. These limitations stem from limited insight into the test capability needs for new systems in a timeframe that supports development of new test capabilities first, a budgeting preprocess that does not support development of new test capability of capacity until there is a "Milestone B" program, a funding process that competes early development test priorities directly against flight and IOT&E testing needs, and a lack of policy to support tester involvement in technology development.

Due to the funding prioritization process, funding for capacity and modernization is usually not available in time to modernize the capability for innovative systems. Air Force modernization funding is planned and programmed using the Test Investment Planning and Programming (TIPP) Process.[xviii] This program competes modernization needs across the Air Force test enterprise. For a need to be considered, there must be a validated test need to support a "Milestone B," or later, acquisition program. The TIPP program funding is allocated across the Five Year Development Plan (FYDP). This process results in new test capability needs not even being considered in the process until five to ten years after the capability is needed. The result is that TIPP investment in early development test capabilities is limited to large maintenance or recapitalization projects.

OSD investment in test modernization is accomplished through the Central Test and Evaluation Investment Program (CTEIP).[xix] Since the services have been gatekeepers to the CTEIP process, early development test needs are not submitted or are really service investment and modernization projects rather than new test capabilities.

Only two new major test capabilities have been constructed at AEDC since the 1970s. The first was the Aeropropulsion Systems Test Facility (ASTF) complex and the second was an

altitude solid rocket motor test facility called J6.[xx] The first was the result of a herculean effort that took support from the White House, Congress, and OSD. The DoD allocated the entire DoD Military Construction Budget (MILCON) budget for one year to fund the project.[xxi] Without the ASTF test capabilities the DoD could not have developed the F22 and F35. The J6 project was the result of a catastrophic rocket engine detonation that destroyed the J5 test facility in the middle of a strategic weapon acquisition system development.[xxii] Both of these projects were funding emergencies that were spawned out of crisis. Without the emergencies, neither would exist and it is unlikely that just the right emergency will occur to ensure the Air Force creates the development capabilities it needs.

The largest factor in development capacity is funding to support the workforce and facility maintenance. Budget cuts between 1991 and 2015[xxiii][xxiv] left the DoD's test and evaluation workforce decimated. Workload is increasing at an all-time high pace. Recently funding for the reactivation of test units to support the fast growing workload has added to budget pressures. Funding has started to increase, but the funding and the time needed to acquire, train, and develop test experts is just not able to keep pace with the quickly increasing test pace. An additional impediment to adequate early development test funding is the prioritization process. Air Force Material Command now uses the Capability Analysis and Risk Assessment (CARA)[xxv] process to prioritize efforts for the execution and budget years. Operating instructions[xxvi] across the Air Force Material Command (AFMC) are being updated to make this process standard across the test enterprise. This process has two major shortfalls as it pertains to capacity. The process competes early development needs against higher priority more mature development needs and it is not forward-looking enough to support large increases in workload.

Recent Progress

One recent example of where technologists and testers have collaborated is in Supersonic Combustion Ramjet (SCRAMJET) research. The results of this collaboration were mixed. The OSD Test Resource Management Center (TRMC) funded Test and Evaluation Science and Technology (T&E S&T) program provided funds to AEDC to develop test technology for use in test conduct and analysis of high-speed weapons. The Air Force Research Laboratory (AFRL) and AEDC collaborated together to advance both system and test technologies. The program resulted in state-of-the-art award winning laser diagnostics, a world unique vitiation affects database, world unique test facility heater technology, thrust accounting systems, computational models, performance models, analysis techniques, innovative flight test techniques and capabilities, and a competitive engine program for cruise missile development. The most important aspect of this collaboration is the advancement and development of the workforce in AFRL, AEDC, and the system developers. Everyone was able to leverage funding from others to make more progress than they could have possibly made alone. However, this collaboration fell apart when funding competition became the issue. The Defense Advanced Research Program Agency (DARPA) took over as the lead agency for the program.[xxvii] NASA offered free support and testing so DARPA decided to collaborate with NASA and locked out both AEDC and AFRL. No one at AEDC is involved in the program, and only a few people from AFRL are involved. The facilities utilized are not capable of supporting the follow-on weapons acquisition. When the program attempts to transition from DARPA to an acquisition program, there will be few experts in the Air Force who can support the development or testing of the system. It will take considerable time and cost to develop the workforce and capabilities to

support the Air Force acquisition. The result will be long delays in the acquisition of a weapon system based on these technologies.

Recent increases in workload have helped bring attention to the funding shortfalls in early development test. This recent increase in workload can be attributed to two things. The first is a reinvigoration of the test rigor. This reinvigoration of test rigor provides real insight to program managers and system developers, as opposed to just providing mountains of data. The second is a focus on owning the technical baseline directly with program offices. Program offices have begun to fund testing directly, instead of through prime contractors. Test analysts have become invaluable to program offices. Programs have requested support developing test plans, analyzing data, developing Requests for Proposals (RFPs), developing Requests for Information (RFI), and evaluating proposals. The need for analysts to support internal testing, customer testing at other locations, and program office support has led to a severe shortage of personnel. Internal policies for hiring both organic test, analysis, and support contractor workforce have limited AEDC's ability to support internal and external customers. Another factor limiting support to the increased workload is the availability of test units. Because there was little or no interaction with the programs in the technology demonstration phase, the increased workload is not projected. When the technology phase workload is done outside of DoD, not only does the valuable collaboration not occur, but often this lack of workload can result in the closure of test capability that could be needed in the future.

An example of where funding is needed to create increase capacity is in the Propulsion Wind Tunnel Complex at AEDC. In the sixteen-foot transonic wind tunnel (16T), a new test and model support cart is needed to provide enough capacity to support the upcoming workload. This cart is 40-foot x 40-foot x 40-foot section of facility that is removed with the test article and

weighs nearly one million pounds. The cost of the cart is approximately $30M and could take as long as two years to construct. In fiscal year 2018, this cart would save nearly 18 weeks of schedule in 16T at a value of nearly $4.5B in program delays. A similar savings is projected in 2020. It is unlikely that the funding process will result in the project getting the needed priority so that funding is available to purchase the cart in time to support testing in 2020

The Air Force developmental test community is trying to implement OSD policy[xxviii] on early tester involvement recommended in the 2008 DSB report on Developmental Test and Evaluation.[xxix] This policy requires the determination of a Responsible Test Organization (RTO) early in the program. One failure of the policy is that the acquisition program manager can decide if this level of scrutiny is really needed, and they can limit support by limiting funding to the RTO.

The collaboration between the OSD T&E S&T program yielded the technologies to construct a suite of new test capabilities to support developmental testing of new hypersonic weapons. While the services did not submit those test capabilities as needs to CTEIP, OSD TRMC (the organization that executes the T&E S&T and CTEIP) secured $350M in the FY17 budget to develop these capabilities. The gains made by this program could be expanded to cover other flight regimes.

Program competitions could be evaluated on wind tunnel based performance estimates. Acquisition demonstration program fly-offs are very costly and can often have limited value to the system development process. These unique systems are designed around the flight demonstration's grading rubric not on the system's mission requirements. After the demo is complete, a redesign of the system is accomplished to meet the system mission requirements. This leads the flight demonstration to being more stunt than system demonstration. At least one

program is currently conducting the “fly-off” in the wind tunnel where force-accounting inputs and stability derivative inputs can be acquired with common test techniques and low uncertainties. This data can then analyzed against the mission requirements. The system performance of competitors can be compared in a direct and precise way avoiding protests on performance evaluation criteria. This competition should be monitored and the technique should be evaluated for expansion to other programs.

Recommendations.

The test community needs the ability to develop and maintain a stable workforce. Conflicts between internal priorities, external customer priorities, and limitations on funding type create inefficiencies in project execution and workforce development. AEDC needs the ability to shift funding and internal project execution to enable the most efficient execution of the test mission. This could be accomplished in a number of ways including institutional funding schemes or a single program element funding strategy. While single program element funding would add flexibility, it could add risk to the budget by making it a target of detractors. An additional benefit to the institutional funding model is the possibility of high utilization of test capabilities by technology developers. Technology developers could have more demonstrated technologies ready, on-the-shelf, to support acquisition programs.

The RTO needs to be independent and the test team needs to predate the “Milestone B” decision for the program itself. For the RTO concept to be effective, funding decisions for the RTO team need to be made by the test community, not by the program office.

The Air Force needs a valid process that can lead to new test capability to support the development of innovative weapon systems. Today no real funding process exists in the Air Force. Successes by OSD in this regard need to be expanded outside of hypersonic.

Collaboration is the key to developing a better test capability base. This collaboration will improve workload forecasting and develop a better workforce. The collaboration between testers, technologists, and program offices enabled by the OSD T&E S&T program needs to be expanded to support development in other flight regimes.

The cost of testing is borne in the acquisition community it supports. To provide for a higher fidelity and more robust test capability base, funding for testing, excluding consumables, should be institutionally funded by the test community. This funding policy would result in programs being incentivized to conduct the proper testing and testers being able to provide the right test capability and capacity mix.

Ground test "fly-off" techniques should be considered as a tool in evaluating competing system proposals. This technique could save considerable time and cost in comparison with traditional fly-off demonstrations.

Conclusions

During the dedication of AEDC, President Truman talked about the need to maintain the very best Air Force and AEDC's role in maintaining that preeminence.[xxx] The best systems are the result of the best engineers utilizing the very best tools. Developmental test is one of these tools. Arguably testing has one of the largest impacts on system suitability when compared to other systems engineering tools. It is important to encourage the use of these best capabilities and maintain expertise through their use. It is also important to ensure facilities are up to date and have the ability to support both test technology and systems development programs. The Air Force funding and use policies, as they pertain to early developmental testing, should be codified in a way to support these goals. To accomplish these goals a number of funding and use policy changes should be investigated. These changes include:

- flexible funding options are needed to enable the shifting of funding to support workload and priority changes;
- RTO funding needs to be independent of program office funding;
- a funding process needs to be developed that supports the development of innovative new test capabilities to support new acquisition programs;
- a process is needed to provide funding for testers to collaborate with technology developers;
- the OSD T&E S&T program should be expanded to additional flight regimes;
- the wind tunnel "fly off' program should be closely monitored and if successful expanded to early system and technology development programs;
- the cost of testing, except for consumables, should be institutionally funded.

These changes would not increase the total cost of testing inside the Department. These changes would result in lower cost and faster development of aerospace systems with much improved performance. A lower-cost, faster-development cycle could yield savings that could be invested in new technologies and new weapon systems. This faster development pace could help the U.S. maintain its advantage in the air.

Notes

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